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SYNOPSIS. Examination of Iowa coal balls from the Des Moines Series has yielded two petrified stem fragments assignable to the arborescent lycopod genus *Lepidophloios*. Details of the leaf cushions and internal stem anatomy are described and compared with similar specimens from Kansas and Illinois coal balls. In light of these observations, criteria presently used to distinguish among species of *Lepidophloios* are re-examined. In particular, the diagnostic features of *Lepidophloios kansanus* (Felix) Eggert and *L. pachydermatikos* Andrews & Murdy are reviewed and determined to represent ontogenetic differences. The probable conspecific nature of the above taxa results in assignment of the Iowa specimens to *L. kansanus sensu lat.*

INDEX DESCRIPTORS: Paleobotany; fossil plants; *Lepidophloios;* coal balls; Iowa Pennsylvanian.

Some 250-300 million years ago, during what geologists refer to as the Pennsylvanian Period, much of the area which presently is Iowa was covered by a vast swamp filled with vegetation. As these plants grew and died, most of their remains fell into the swamp water and accumulated to form thick peat-like layers which were ultimately reduced to coal. Some of the plant remains, however, escaped conversion to coal and were instead preserved in the form of impressions, compressions, or petrifactions. The study of such fossil remains provides us with a glimpse of the now extinct plants which once flourished in the coal age swamps of Iowa.

During the summer of 1970 two petrified stem fragments assignable to the arborescent lycopod genus *Lepidophloios* were collected near Oskaloosa, in Mahaska County, Iowa. The specimens were preserved in subspherical masses of calcium carbonate and pyrite, commonly referred to as "coal balls." In central Iowa such coal balls frequently occur in the coal seams of the Des Moines Series, Cherokee Group, of Middle Pennsylvanian age (Landis, 1965).

Although the occurrence of petrified *Lepidophloios* specimens in Iowa coal balls has previously been noted by Andrews & Murdy (1958) and Darrah (1969), the present study represents the first detailed account of such material.

## DESCRIPTION

One fragmentary weathered specimen (U. Ia. coal ball #801) was collected from gob piles near the Lost Creek Mine Office located five miles south of Oskaloosa, Iowa. This specimen (Figs. 1, 2) consists of several rhombic leaf cushions and the immediately subjacent periderm. As is characteristic of the genus *Lepidophloios*, these leaf cushions are considerably wider than they are tall and have acute lateral angles. The cushions on this specimen measure about 35-40 mm in width by 15 mm in height.

A second and more complete specimen (U. Ia. coal ball #802) was collected from gob piles near the Mich Coal Company Office located one mile east of Oskaloosa. This specimen (Figs. 3-6) represents a portion of a relatively large stem in which the leaf cushions, periderm and central vascular cylinder have been preserved. Details of the internal anatomy were observed by sectioning the specimen and employing the cellulose peel technique as described by Stewart & Taylor (1965). Tangential sections through the leaf cushions (Figs. 3, 4) show the typical *Lepidophloios* outline with individual cushions measuring 28-30 mm wide by 9-10 mm high. Close examination (Fig. 4) shows near the base of each cushion a triangular vascular trace (t) flanked by a pair of oval parichnos strands (P). Slightly above the middle of each cushion a dark circular area marks the location of the ligule pit (1).

Immediately subjacent to the leaf cushions is a zone of secondary cortical tissue, or periderm (Fig. 5), which is 6-7 mm wide. The cells of the periderm are radially aligned, elongate elements. These fibre-like cells are divided by one or more transverse septa and have been frequently described as "chambered." As is often the case in *Lepidophloios* specimens, little of the primary cortical tissue has been preserved.

At the center of the stem the somewhat crushed vascular cylinder exhibits only primary tissues (Fig. 6). Large metaxylem tracheids comprise the bulk of the primary xylem which forms a layer (M) approximately 2 mm in radial thickness around the central pith (O). These metaxylem elements show a centripetal increase in diameter, have prominent scalariform thickenings, and reach lengths of over 25 mm. Smaller protoxylem elements occur to the outside of the metaxylem in an exarch arrangement. Many small groups of protoxylem cells (X) extend outward from the stele, causing it to appear spiny or "coronate" in transverse view. The center of the stele is occupied by a large pith consisting of thin-walled, essentially isodiametric cells arranged in vertical files.

## DISCUSSION

The specimens described above bear close resemblance to two species of *Lepidophloios* previously described from Kansas and Illinois coal balls. These are *Lepidophloios pachydermatikos* Andrews & Murdy (1958), and *L. kansanus* (Felix) Eggert (1961).

To facilitate comparison of the Iowa material with these two established taxa, diagrammatic cross sections of each are presented in Figs. 7-9. In all three cases the central vascular cylinder consists of a coronate siphonostele. *Lepidophloios kansanus* (Fig. 7) was originally characterized by Felix (1952) as having stems possessing broad zones of secondary xylem and periderm. The extensive development of these secondary tissues usually resulted in the loss of the leaf cushions. In contrast to this, stems of *L. pachydermatikos* (Fig. 8) were characterized as possessing no secondary xy-

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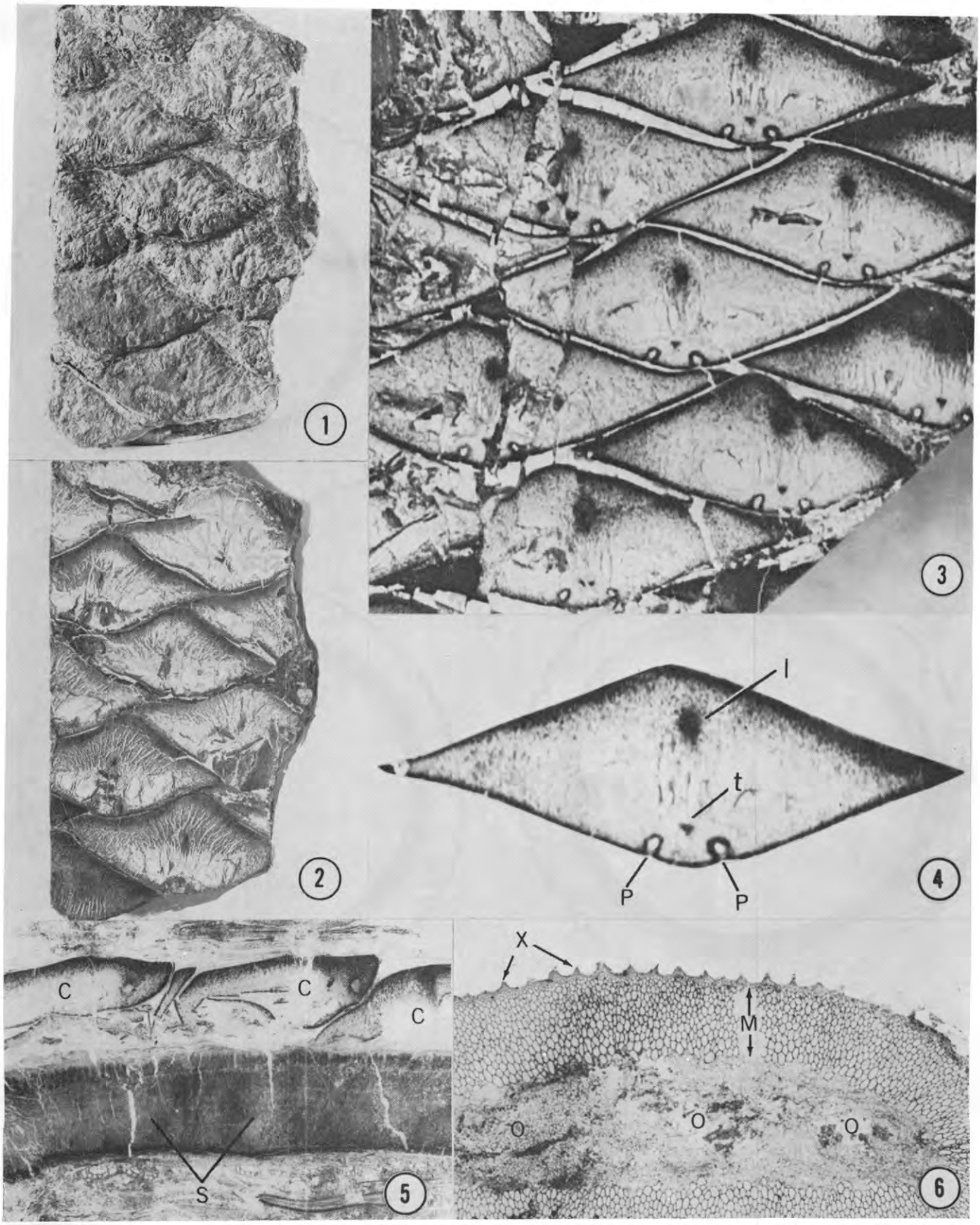


PLATE. I. (Figs. 1-6) Fig. 1. Fragment of a weathered coal ball showing rhombic leaf cushions. U. Ia. c.b. #801 X1. Fig. 2. Same specimen as in fig. 1 but with surface of cushions ground and etched. U. Ia. c.b. #801 X1. Fig. 3. Leaf cushions in tangential section. U. Ia. c.b. #802 X2. Fig. 4. Enlarged view of uppermost leaf cushion from fig. 3 showing vascular trace (t) parichnos strands (P), and area of ligule pit (l). U. Ia. c.b. #802 X3. Fig. 5. Oblique transverse section through leaf cushions (C) and subjacent periderm (S). U. Ia. c.b. #802 X3. Fig. 6. Transverse section through somewhat crushed vascular cylinder with central pith (O) surrounded by metaxylem (M) and small protoxylem points (X). U. Ia. c.b. #802 X6.

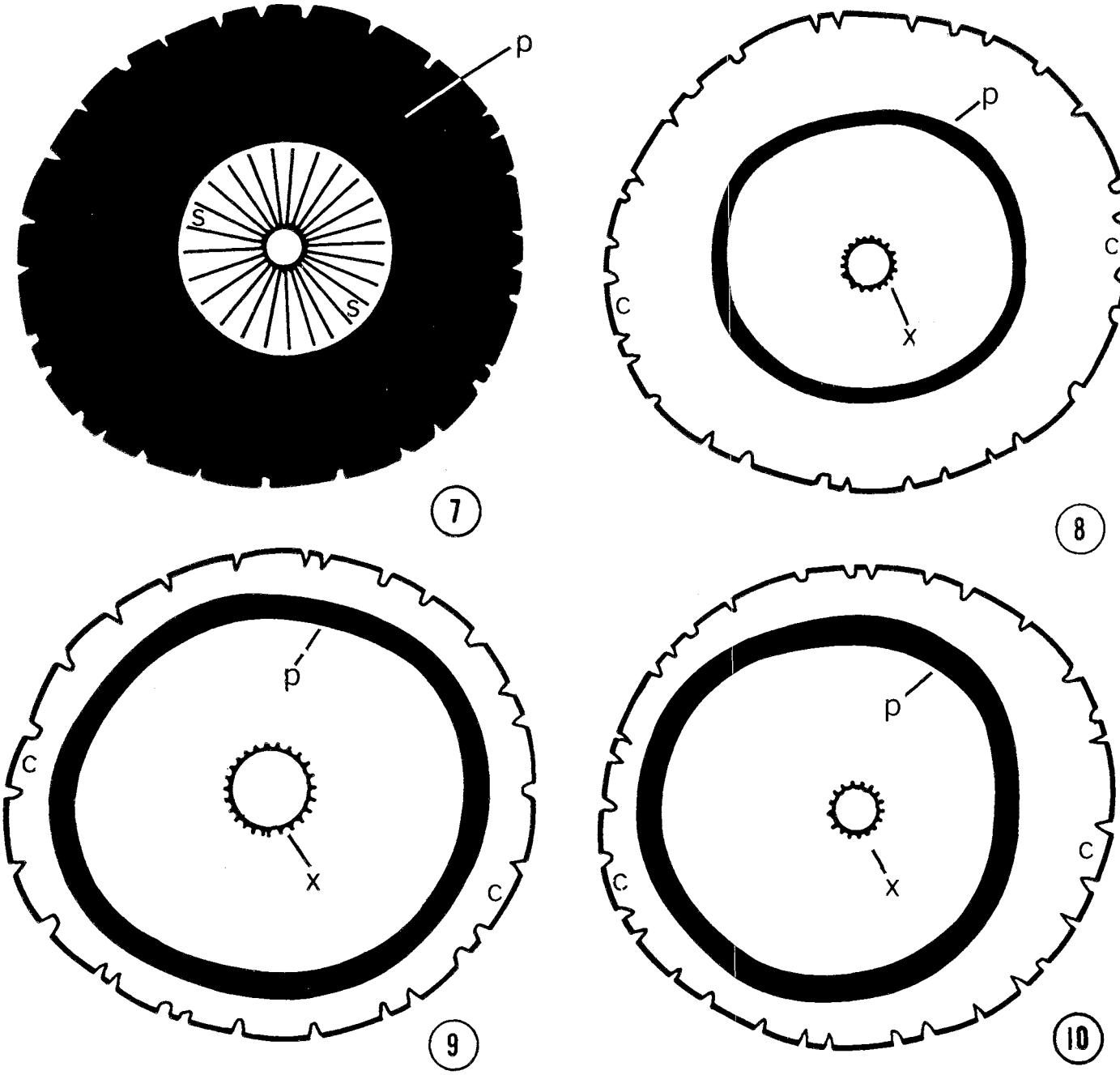


PLATE II. (FIGS. 7-10) Idealized diagrammatic cross sections through various *Lepidophloios* specimens. One half natural size. Fig. 7. Typical decorticated specimen of *L. kansanus sensu* (Felix) Eggert with broad zones of secondary xylem (S) and periderm (P). Fig. 8. Typical specimen of *L. pachydermatikos sensu* Andrews & Murdy with only primary xylem (X) and a narrow periderm (P). Fig. 9. Iowa specimen showing primary xylem (X) and periderm (P) subjacent to leaf cushions (C). U. Ia. c.b. #802. Fig. 10. Paratype of *L. pachydermatikos* showing acentric development of periderm (P) in relation to primary xylem (X) and leaf cushions (C). Univ. Kansas c.b. #1079.

lem, or only a limited amount of "abnormal" wood, and a narrow periderm located deep within the cortex. The Iowa material (Fig. 9) clearly shares various features in common with both of these species, yet does not fully satisfy the diagnosis of either taxon. Its apparently intermediate structure raises some serious questions about the criteria which have previously been used to distinguish between *L. kansanus* and *L. pachydermatikos*.

Eggert (1961), in reviewing the morphology and determinate growth pattern of various arborescent lycopods, noted that the initiation and development of secondary tissues was a function of maturity and location within the plant body.

He therefore cautioned against the practice of using the presence or absence of secondary tissues as criteria for species identification. On the basis of this reasoning he felt justified in assigning to *L. kansanus* a specimen (Yale c.b. #284) which lacked any secondary xylem. Subsequently Delevoryas (1967) described a decorticated specimen of *L. kansanus* which possessed a large primary xylem cylinder and a varying amount of secondary xylem ranging from 0-3 mm in width. The report of such a specimen further strengthens the argument that the presence of secondary xylem represents a variable ontogenetic feature and not a species-specific characteristic.

Similar logic can be applied in the case of periderm development. In addition to variations in the degree of periderm development that might be expected as a function of maturity and location in the plant, there also appears to have been considerable variation in the location of the periderm in relation to the cortex. An examination of one of the paratypes of *L. pachydermatikos* (Fig. 10) reveals surprising variation in the proximity of the periderm to the leaf cushions. In this specimen the distance from leaf cushions to outermost periderm elements varied from 4 mm on one side of the stem to 17 mm on the other.

## TAXONOMIC TREATMENT

Once one acknowledges the inadequacy of using the occurrence of secondary tissues as a means of distinguishing among species of arborescent lycopods, there remains no clear distinction between *L. kansanus* and *L. pachydermatikos*. Indeed, it appears likely that they may even represent different portions of the same species. *Lepidophloios kansanus*, with its usually well developed secondary tissues, may have represented portions of the main trunk, while *L. pachydermatikos*, with its lack of extensive secondary growth, probably represented younger or more apical portions of the plant. According to this model, the Iowa specimen (Ia. c.b. #802) would appear to represent an intermediate location or stage of maturation where periderm development had progressed without the initiation of secondary xylem.

In view of our inability to determine any satisfactory distinction between *L. kansanus* (Felix) Eggert and *L. pachydermatikos* Andrews & Murdy and considering the likelihood of their being conspecific, we have assigned the Iowa specimens to *L. kansanus* on the basis of its nomenclatural priority. We have, however, refrained from formally synonymizing these taxa and providing an emended species description until more is known concerning the ontogeny and morphological variability of *L. kansanus sensu lat.*

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